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Compilation of Averaged Meteorological Profiles by Marsden Square

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Naval Command, Control and
Ocean Surveillance Center
RDT&E Division

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Tropospheric Branch

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Propagation Division

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1. INTRODUCTION

During the development of the Naval Oceanic Vertical Aerosol Model (NOVAM) [1] and its predecessor, the Navy Aerosol Model (NAM) [2], much work was done to correlate electrooptical conditions with the meteorology of the atmosphere. Using commonly measured surface meteorological data such as visibility, winds, and profiles of temperature and humidity, NOVAM will describe optical and infrared propagation properties of the marine boundary layer. NOVAM's predictions depend upon the accuracy of the input meteorological parameters. The user must have access to a meteorological database for a particular area in order to effectively use the model. This is true of most meteorological models. Obviously, there are times when data may be incomplete or unavailable to the user.

There is a wealth of worldwide meteorological data archived in various centers around the United States. These data have been collected, analyzed, and reduced to estimated meteorological profiles available to users of NOVAM. It is no longer necessary to have current data at hand to make a prediction using the model.

Although these estimated profiles were originally developed for use in NOVAM, they can be a valuable source of data for other modelers and researchers as well. They are thus being made available as a meteorological database.

2. SOURCES OF DATA

Sources of meteorological data used in the estimated profiles include the Naval Oceanography Command Detachment Asheville (formerly called Fleet Numerical Meteorology and Oceanography Detachment), the National Climatic Data Center (NCDC), and the National Oceanic and Atmospheric Administration (NOAA). These centers have meteorological databases dating back as far as 1854. There have been several consolidations of data and extensive quality control.

2.1 SURFACE MARINE DATA

The surface meteorological data used in the estimated meteorological profiles are from *The CD-Marine Access and Retrieval System* [3], which is based upon the Marine Climatic Atlas of the World. It was produced by the Naval Oceanography Command Detachment Asheville and NCDC, a component of the NOAA, under the authority of the Commander, Naval Oceanography Command. Parameters from this database include air temperature, dewpoint temperature, sea surface temperature, wind speed, wind direction, wave height, and air pressure. Relative humidity was calculated from dewpoint and air temperatures.

The CD-Marine Access and Retrieval System had data averaged by month for individual Marsden Squares over all the world's oceans. Figure 1 [4] shows most of the Marsden Square worldwide grid of 10-degree latitude-longitude squares. (The polar regions are not shown in the figure.)

Visibility data were not available from *The CD-Marine Access and Retrieval System.* They were obtained from NCDC for the years 1988 to 1993 in a database called *Surface Marine Data.* The data were well documented and quality coded [5]. Visibility data from this set, consisting of individual observations, were first run through a program to remove any data flagged with any NCDC error codes. They were then averaged by month per Marsden Square.

NCDC receives its surface marine climatological data from several sources: over 100 participating maritime countries, the NOAA Data Buoy Center, Navy ships, ships in the U.S. Voluntary Observing Fleet, and the Environmental Research Lab, and other special sets are added periodically [5]. Duplicate data entries are removed during several stages of processing, with questionable data flagged and quality coded.

2.2 ABOVE SURFACE AIR OBSERVATIONS

Information on temperature inversions is among the parameters required by NOVAM, hence, sounding observations for the first 6000 meters above the ocean surface are included in the estimated profiles. The *NCDC Upper Air Digital Files,* TD-6200 Series [7] includes sounding observations from several sources: the National Weather Service, U.S. Navy, and several foreign stations whose data receive quality control at NCDC. These files contain individual observations dating back to 1946.

For the purposes of this data set, the last five years, 1988 to 1993, were used. Each observation was processed using the same smoothing and filtering routines contained in NOVAM to determine whether temperature inversions were present. The profiles indicate three possibilities: the free convection mode is characterized by no inversion, the weak convection mode by two inversions, and the developed boundary layer by the presence of one inversion. If inversions were found, the height, air temperature, pressure, and relative humidity just above and just below the inversion were recorded. An average for each month was determined after the individual profiles were processed for each Marsden Square.

3. THE ESTIMATED PROFILES

The estimated profiles include Marsden Squares in which any part is over water. Continental squares are not included. The polar regions are not included due to a lack of available data. Figure 2 shows all the Marsden Squares for which data are available [4].

Table 1 shows a sample of the data available in the estimated meteorological profiles. Table 2 names the parameters and units for each column in the profile. The database in table 1 is arranged by Marsden Square number, listing each of the 12 monthly averages for that square. The square number and month are listed in columns 1 and 2, respectively. Columns 3 through 10 are the surface meteorological observations: pressure, air temperature, dewpoint, wind speed, wind direction, relative humidity, sea surface temperature, and visibility. Columns 11 through 24 are related to the temperature inversion information in the first 6000 meters above the ocean surface.

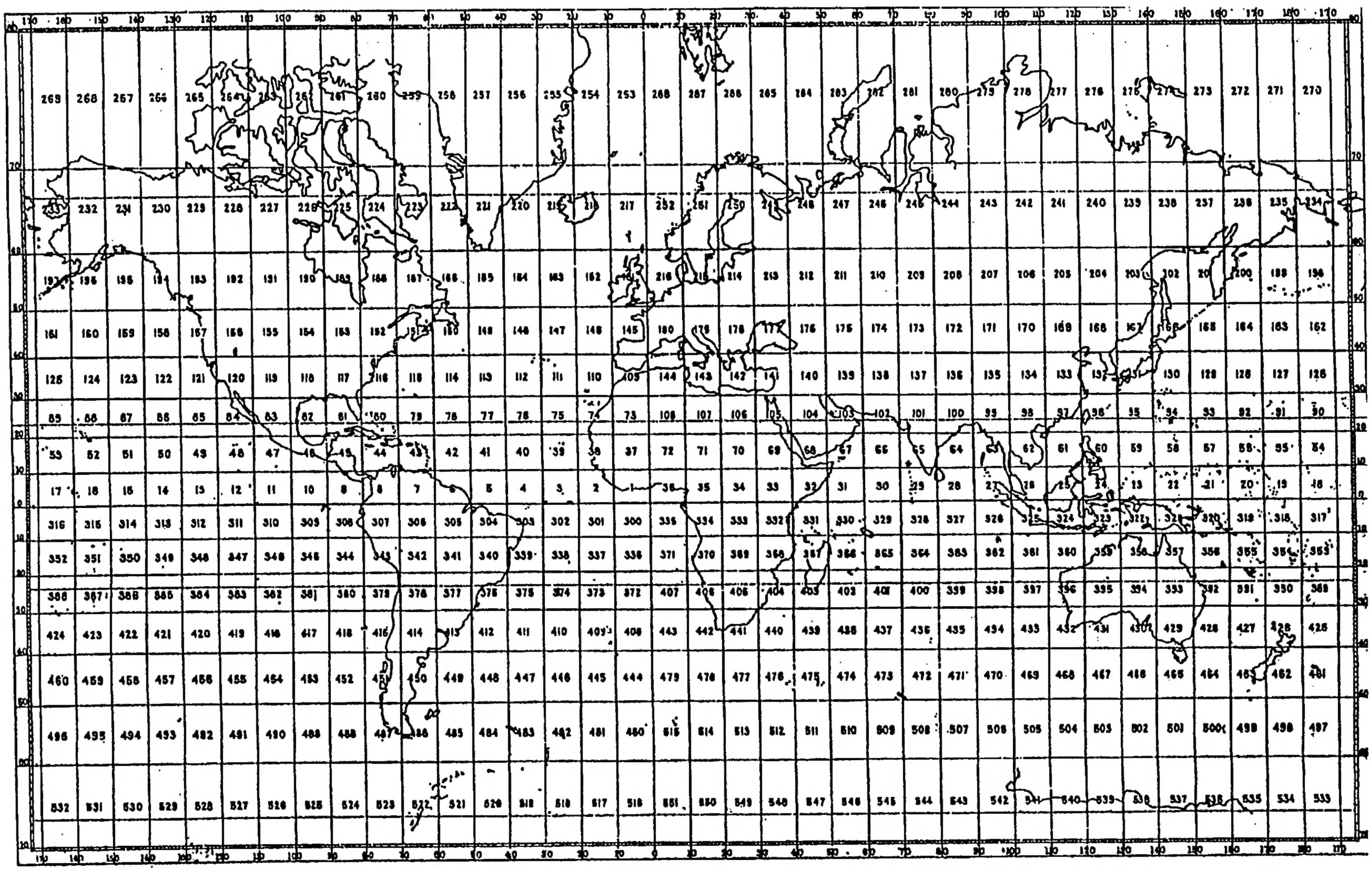

Figure 1. Marsden Square grid. Northern latitudes are positive, southern latitudes are negative. Eastern longitudes are positive, western longitudes are negative.

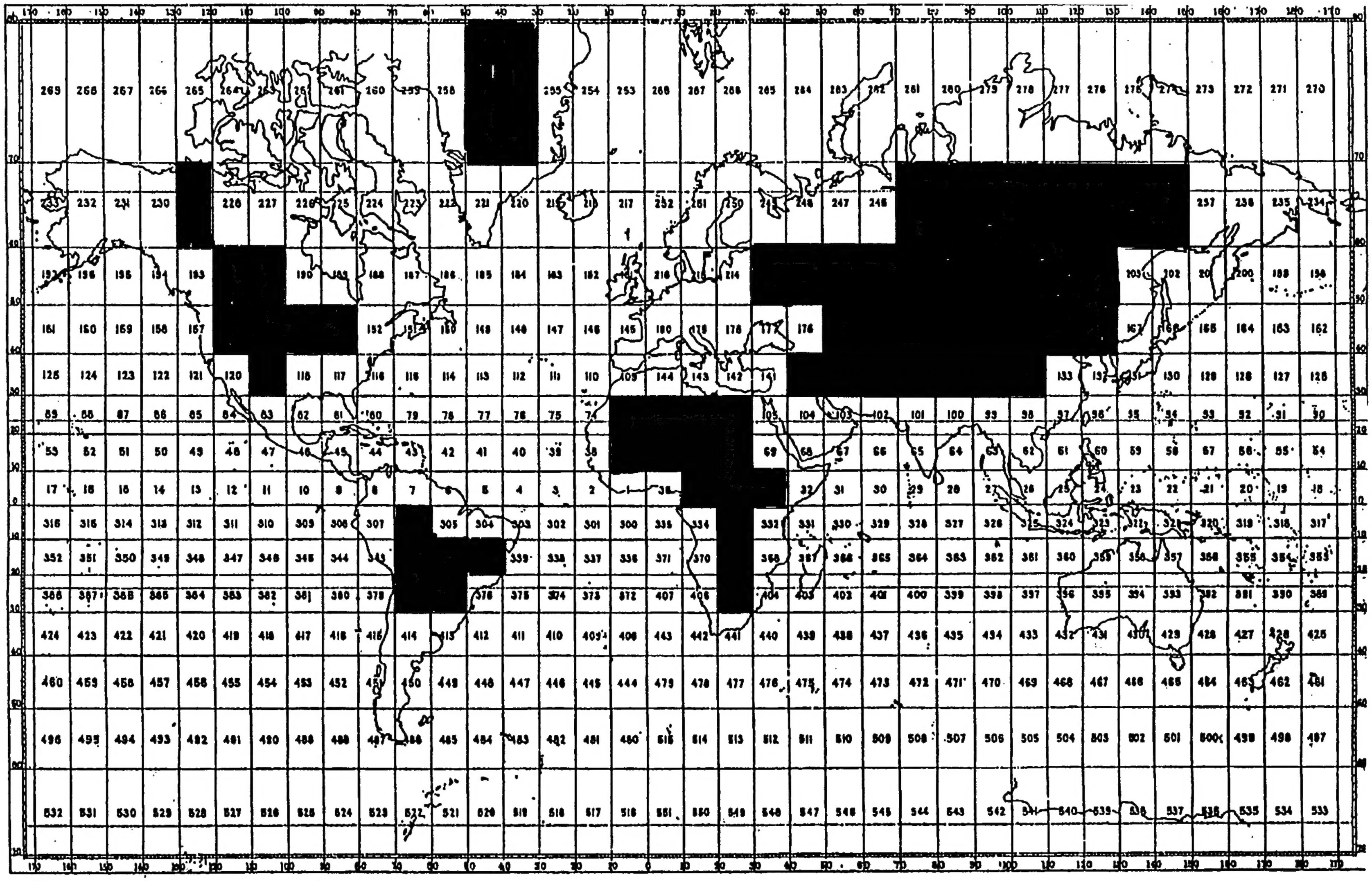

Figure 2. Marsden Square grid showing squares for which estimated meteorological data are available. Polar regions and squares exclusively over land are not included.

Table 1. Sample of data available in the estimated meteorological profiles.

sq #	mo	pres mB	AT C	DPT C	WS m/s	WD deg	RH %	SST C	Vis km	# inv	PTsl	MRsl	Ht 1	PTb1	Mrb1	PTa1	Mra1	Ht 2	PTb2	PTa2	Mra2	inv code
101	1	1013.9	23.3	17.5	4.6	0	68.8	23.5	20	0	22.1	12.5	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	2	1012.4	23.9	19.5	4.1	315	75.5	23.7	20	0	22.9	14.3	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	3	1010.5	25.4	21.2	4.4	315	76.7	24.8	10	0	24.5	15.9	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	4	1008.3	26.8	23.2	5.3	315	79.8	26.3	20	0	26.1	18.1	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	5	1006.6	28.2	25.1	5.7	270	82.5	28.0	15	0	27.6	20.4	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	6	1002.4	29.0	25.9	7.3	225	82.6	28.7	10	0	28.8	21.5	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	7	1001.7	28.0	25.6	9.2	225	86.2	27.9	20	0	27.9	21.1	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	8	1004.0	27.3	25.3	7.4	270	88.3	27.0	15	0	27.0	20.6	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	9	1006.9	27.6	24.5	5.3	270	82.5	27.1	10	0	27.0	19.6	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	10	1010.0	27.9	23.8	3.8	315	77.5	27.5	20	0	27.0	18.8	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	11	1012.1	26.8	20.9	3.8	0	68.9	26.6	20	0	25.8	15.6	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
101	12	1013.5	24.7	18.7	4.1	45	68.1	24.9	20	0	23.6	13.6	-99	-99	-99	-99	-99	-99	-99	-99	-99	2
102	1	1016.1	22.0	15.1	3.5	0	63.9	23.3	20	1	20.7	10.6	1642	27	3.4	30.9	2.4	-99	-99	-99	-99	1
102	2	1014.6	23.3	17.8	4.0	315	70.2	23.3	20	1	22.1	12.6	2371	31.8	4.1	34.1	3.1	-99	-99	-99	-99	1
102	3	1012.2	24.6	20.0	4.6	270	74.7	24.6	20	0	23.6	14.6	-99	-99	-99	-99	-99	-99	-99	-99	-99	1
102	4	1010.3	26.4	23.2	5.7	270	82.0	26.2	20	1	25.5	17.9	300	27.1	12.1	32.6	7.0	-99	-99	-99	-99	1
102	5	1007.0	28.3	25.1	5.5	225	82.2	28.3	20	1	27.7	20.2	576	31.8	15.1	38.3	7.6	-99	-99	-99	-99	1
102	6	1001.3	29.0	25.6	7.2	225	81.5	29.6	10	2	28.9	21.0	375	31.8	17.8	39.2	8.4	5607	52.3	2.0	53.6	1
102	7	999.2	28.5	25.9	7.0	225	85.2	27.9	10	1	28.6	21.4	466	29.6	16.8	39.4	9.2	-99	-99	-99	-99	1
102	8	999.8	27.1	25.1	6.7	225	87.8	27.6	10	2	27.1	20.2	755	30.0	14.5	37.9	8.4	5180	51.7	1.3	52.7	1
102	9	1005.0	27.7	24.6	5.4	248	82.9	27.4	20	2	27.3	19.7	392	28.5	15.4	34.3	7.7	4560	46.9	2.9	49.6	1
102	10	1012.0	27.4	24.0	3.9	293	80.7	27.7	20	1	26.4	18.7	322	27.4	14.3	31.1	7.0	-99	-99	-99	-99	1
102	11	1014.2	25.9	20.1	3.5	0	69.8	26.6	20	0	24.7	14.7	-99	-99	-99	-99	-99	-99	-99	-99	-99	1
102	12	1015.8	23.1	17.0	3.4	45	66.5	24.5	20	1	21.8	11.8	1951	28.4	3.3	22.5	1.7	-99	-99	-99	-99	1
103	1	1017.2	21.2	15.5	4.5	315	68.8	22.4	20	0	19.8	10.8	-99	-99	-99	-99	-99	-99	-99	-99	-99	1
103	2	1015.7	20.9	15.5	5.8	315	70.1	21.8	20	1	19.6	10.8	1160	23.3	5.2	26.6	2.8	-99	-99	-99	-99	1
103	3	1012.8	23.2	17.4	4.9	315	69.1	23.2	20	1	22.1	12.3	373	22.7	9.1	26.8	4.4	-99	-99	-99	-99	1
103	4	1010.0	25.7	21.2	4.0	315	75.1	25.1	20	1	24.9	15.7	203	26.6	14.3	31.3	6.9	-99	-99	-99	-99	1
103	5	1005.5	29.0	24.2	4.2	315	74.1	28.0	20	1	28.5	19.0	252	31.3	17.6	35.7	8.8	-99	-99	-99	-99	1
103	6	1000.0	31.4	25.5	4.4	270	70.7	30.0	10	2	31.4	21.1	381	33.0	17.6	17.5	6.5	4677	50.4	4.3	52.9	1
103	7	996.0	31.1	27.1	4.2	315	78.6	30.8	10	1	31.4	23.1	621	34.0	18.9	40.6	9.9	-99	-99	-99	-99	1
103	8	999.4	31.2	27.3	3.8	315	78.8	31.0	10	2	31.3	23.2	247	30.4	18.0	39.2	8.5	5876	53.8	2.0	56.3	1
103	9	1005.0	30.9	26.7	3.4	315	77.4	31.3	20	2	30.5	22.3	559	31.1	15.3	37.0	7.8	5145	49.9	2.3	52.8	1
103	10	1012.0	29.5	23.6	2.9	315	69.5	30.1	20	1	28.5	18.3	708	28.1	12.9	31.9	7.1	-99	-99	-99	-99	1

Table 2. Column contents of the estimated meteorological profiles shown in table 1.

Column	Parameter	Units
1	Marsden Square Number	integer
2	Month	integer
3	Pressure at Sea Level	millibars
4	Air Temperature at Sea Level	degrees C
5	Dewpoint Temperature	degrees C
6	Wind Speed	meters/sec
7	Wind Direction	degrees
8	Relative Humidity at Sea Level	percent
9	Sea Surface Temperature	degrees C
10	Visibility	kilometers
11	Number of Temperature Inversions	integer
12	Potential Temperature at Sea Level	degrees C
13	Mixing Ratio at Sea Level	g/kg
14	Height of 1st Inversion	meters
15	Potential Temp Below 1st Inversion	degrees C
16	Mixing Ratio Below 1st Inversion	g/kg
17	Potential Temp Above 1st Inversion	degrees C
18	Mixing Ratio Above 1st Inversion	g/kg
19	Height of 2nd Inversion	meters
20	Potential Temp Below 2nd Inversion	degrees C
21	Mixing Ratio Below 2nd Inversion	g/kg
22	Potential Temp Above 2nd Inversion	degrees C
23	Mixing Ratio Above 2nd Inversion	g/kg
24	Inversion Code	integer

Column 11 tells how many inversions are present (0, 1, or 2), and if there are any, column 14 tells the height of the first and column 19 tells the height of the second. If information is not applicable, the entry is -99. An example of non-applicable data would be any information in the columns for a second inversion where column 11 indicated there was only one inversion.

The columns marked "PT--" and "MR--" refer to the potential temperature and mixing ratio at sea level or just above and just below the inversion. The potential temperature of the air is defined as that temperature obtained by adiabatic expansion or compression to 1000 mb [6]. It is a function of temperature and pressure. The mixing ratio is a measure of the moisture content of the air, defined as the mass of water vapor per unit mass of dry air in the mixture [6]. It is a function of temperature, relative humidity, and pressure.

Measurements of potential temperature and mixing ratio are used because they yield a relatively

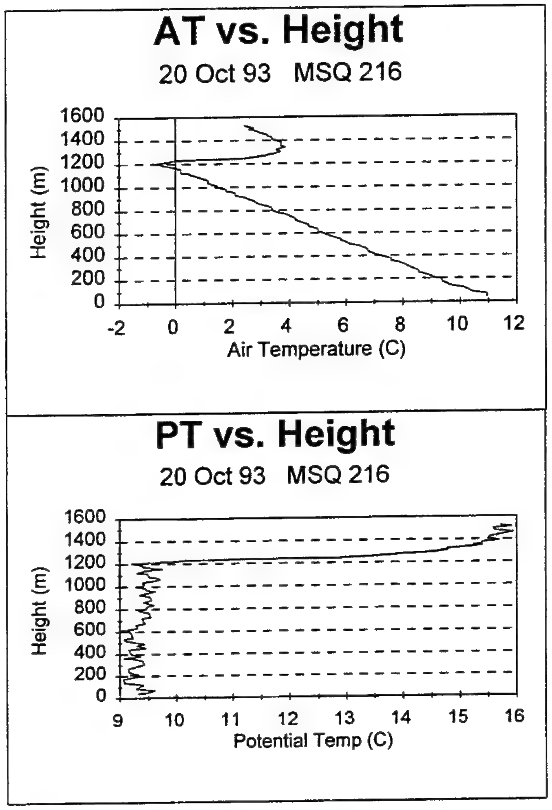

Figure 3. Comparison of air temperature and potential temperature versus height.

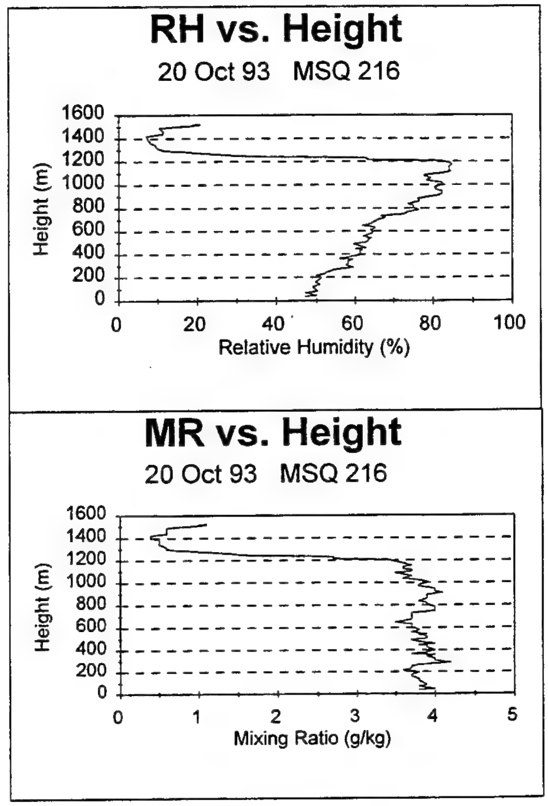

Figure 4. Comparison of relative humidity and mixing ratio versus height.

constant value between inversion levels. Figure 3 compares air temperature and potential temperature for data recorded October 20, 1993, in the North Sea. Figure 4 compares relative humidity and mixing ratio for the same data. It can be seen that using potential temperature and mixing ratio, the values just above and just below inversions will remain relatively constant throughout that level, and so they more reasonably estimate the value of that level. They also clearly define the point of inversion. Figure 5 is a stylized graph showing the locations of sea level, first inversion and second inversion, and their general trends versus height.

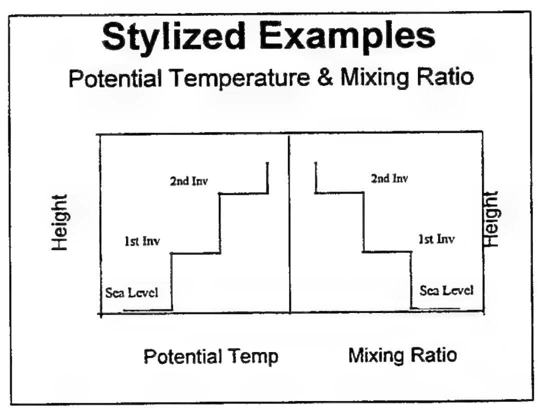

Figure 5. Stylized example demonstrating how potential temperature and mixing ratio typically vary with altitude for the case of two inversions.

4. COMPARISONS TO IN SITU DATA

After the estimated profiles were compiled, comparisons were made to data taken during three field experiments in three separate locations and years. Data from Marsden Square 121 were recorded in June 1994, during an Infrared Analysis Measurement and Modeling Program (IRAMMP) experiment off the coast of Monterey, California. Data from Marsden Square 216 were recorded in October 1993, during the Marine Aerosol Properties and Thermal Imager Performance (MAPTIP) experiment off the coast of the Netherlands in the North Sea. Data from Marsden Square 116 were recorded in November 1992, during another IRAMMP experiment off the coast of Cape Hatteras, North Carolina. In all three cases, we had surface meteorological data from various sources and vertical meteorological profiles up to 1500 meters recorded by the Naval Command, Control and Ocean Surveillance Center RDT&E Division (NRaD) instrumented aircraft.

Results of these comparisons are encouraging. While one cannot expect an average profile to match exactly with meteorological conditions at any given time, there are indeed trends in a given location during a given month. As can be seen in the graphs of figures 6, 7, and 8, the estimated profiles compared quite well with the data taken at the specific dates and locations mentioned. These graphs are normalized. The data from the estimated profile were considered to be 100% for each parameter. The in situ data are marked as their percentage higher or lower than profile data.

Figure 6 is for June, in Marsden Square 121 off the California coast. The surface data agree

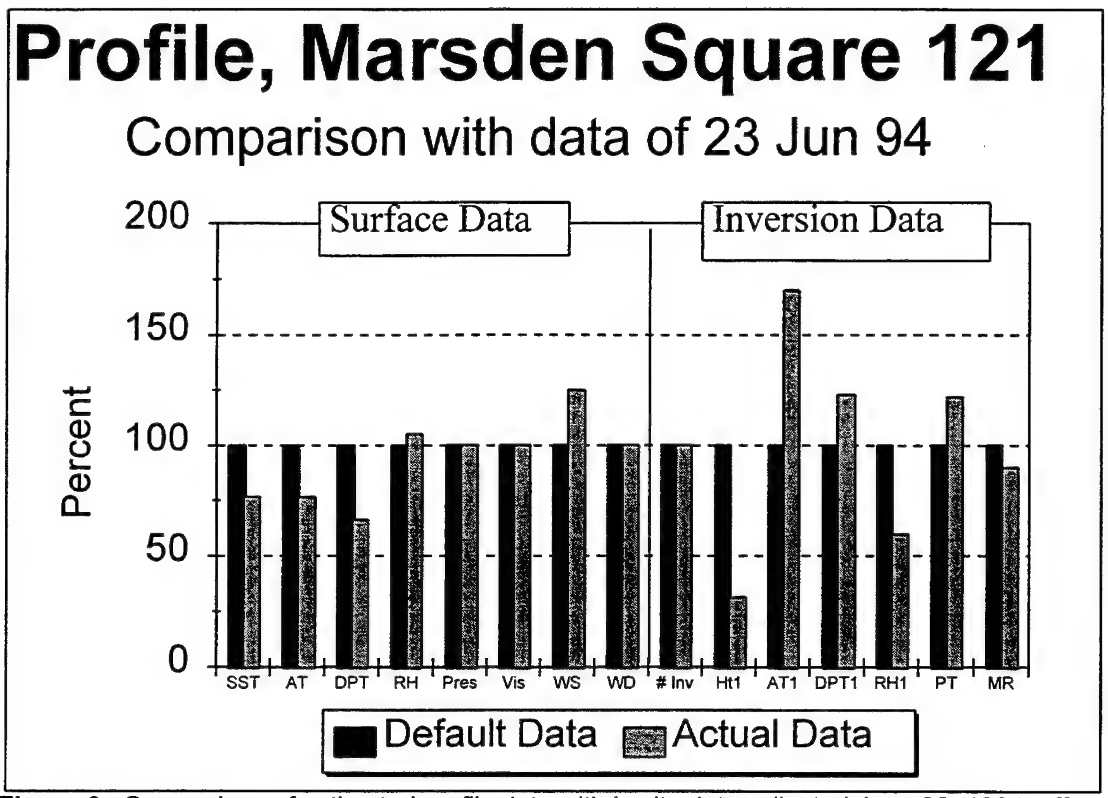

Figure 6. Comparison of estimated profile data with in situ data collected June 23, 1994, off the coast of Monterey, California. The estimated profile data are normalized to 100%.

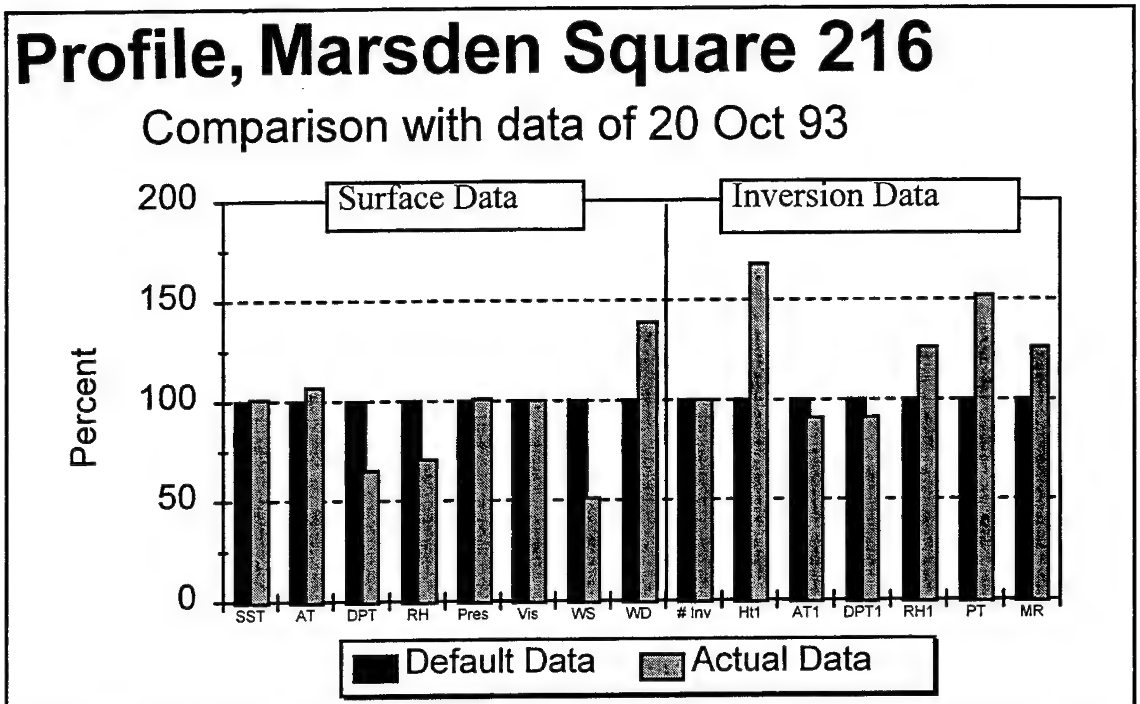

Figure 7. Comparison of estimated profile data with in situ data collected October 20, 1993, in the North Sea off the coast of the Netherlands. Profile data are normalized to 100%.

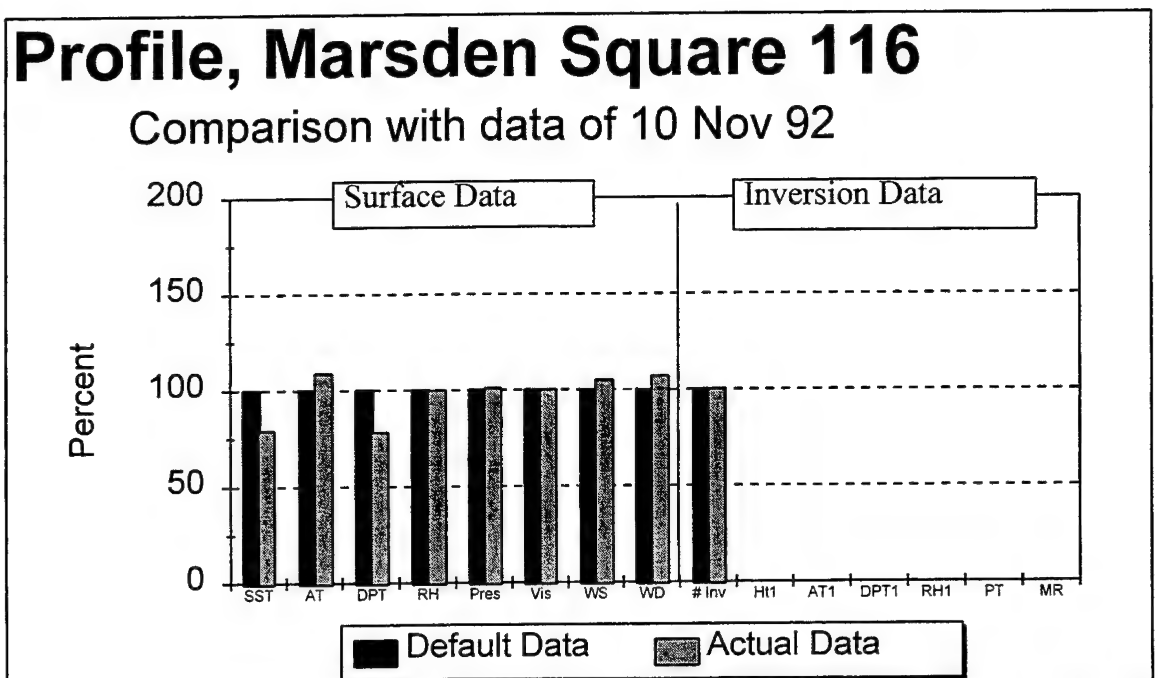

Figure 8. Comparison of estimated profile data with in situ data collected November 10, 1992, off the coast of North Carolina. Since there were no inversions in this case, the section on inversion information is left blank. Profile data are normalized to 100%.

quite well. Relative humidity, pressure, visibility, and wind direction were almost exactly as predicted. The actual wind speed was slightly higher than the estimated profile value, which may account for the actual temperatures being slightly lower. The profile correctly predicted one inversion, although it occurred at a lower altitude (170 m) than the estimate (540 m). That accounts for the inversion temperatures being higher and relative humidity lower than the estimate, which was for a higher elevation.

Figure 7 is for October, in Marsden Square 216 in the North Sea. Here again, the surface data and the profile data agreed quite well. The wind, however, was from the northwest (313 degrees), while the average profile for October predicted wind from the southwest (225 degrees). The profile correctly predicted one inversion, but it occurred at a higher altitude than expected, which is why the temperatures are a bit lower than predicted.

Figure 8 is for November, in Marsden Square 116 off the North Carolina coast. Actual surface data are in very close agreement with the estimated profile. The profile accurately predicted no inversions below 1600 meters, which is as high as our airplane recorded that day. (The estimated profile for that month does predict one inversion at a higher elevation.)

The estimated values for air temperature, dewpoint, and humidity can be calculated from the equations for potential temperature and mixing ratio. These are given in the profiles at sea level, and just below and just above any inversions present. If there are no inversions or only one inversion, the profile will list -99 where meteorological data for inversions would have been if they existed.

The last column in the profiles shows an inversion code. This is either a 1, 2, or 3. A "1" indicates that data for that row were directly calculated from compiled data for that Marsden Square and month. A "2" indicates that there were insufficient data, and averages were combined with the data from the preceding or following month, or from a neighboring Marsden Square. A "3" indicates that the data were from a nonadjacent Marsden Square, as close as possible to that square. Obviously, those coded "1" are considered most accurate.

5. CONCLUSIONS

Researchers in the meteorological sciences will benefit from the compilation of these estimated profiles and can use them for default values where no data are available. While no average forecast can predict an individual occurrence, these profiles give a reasonable estimate of what to expect at a given location in a given month. They should prove to be an asset to modelers.

For a copy of the estimated meteorological profiles, send your request to Kathleen Littfin at NCCOSC RDT&E Division, Propagation Division, Code 883, 49170 Propagation Path, San Diego, CA 92152-7385, or call (619) 553-6939. Send e-mail requests to littfin@nosc.mil. Please specify whether you want the database on disk or CD.

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13. ABSTRACT *(Maximum 200 words)*

Researchers in the atmospheric sciences need meteorological data from various areas of the world to test and validate models. There is often a lack of available meteorological data necessary for required inputs to these models. Meteorological parameters vary widely depending on time of year, location, wind direction, etc. Using existing worldwide databases, averaged meteorological profiles have been developed for use when in situ measurements are not available. The profiles provide estimated parameters averaged by month for select Marsden Squares. Measured meteorological data and estimated profiles are compared.

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